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ABSTRACT

In this monograph we begin by situating the technological and historical origins of the World Wide Web in hypermedia systems that were conceptualized during the World War II era and first developed decades before the Web. We then review the cross-disciplinary theoretical and empirical literature on the uses and effects of educational hypermedia. This literature is spread across fields as diverse as cognitive and educational psychology, geography, educational technology, engineering, environmental psychology, and computer science. From this literature we specifically focus on: (1) hypermedia theory applicable to educational uses and effects of the World Wide Web, (2) empirical research on how individuals use hypermedia systems; and (3) empirical research on the cognitive effects of hypermedia systems. We conclude by discussing the implications of this theory and research in an effort to provide a framework for research on formal and informal learning via the World Wide Web. (Contains 118 references.) (Author)

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Research Monograph No. 15

Using Hypermedia Research to Advance the Study of Learning on the World Wide Web

William P. Eveland & Sharon Dunwoody

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Using Hypermedia Research to Advance the Study of Learning on the World Wide Web

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Abstract

In this monograph we begin by situating the technological and historical origins of the World Wide Web in hypermedia systems that were conceptualized during the World War II era and first developed decades before the Web. We then review the cross-disciplinary theoretical and empirical literature on the uses and effects of educational hypermedia. This literature is spread across fields as diverse as cognitive and educational psychology, geography, educational technology, engineering, environmental psychology, and computer science. From this literature we specifically focus on: (1) hypermedia theory applicable to educational uses and effects of the World Wide Web; (2) empirical research on how individuals use hypermedia systems; and (3) empirical research on the cognitive effects of hypermedia systems. We conclude by discussing the implications of this theory and research in an effort to provide a framework for research on formal and informal learning via the World Wide Web.

Scholars interested in the educational uses and effects of the World Wide Web may believe that, because searches of electronic data bases and recent issues of academic journals produce few studies with "World Wide Web" or "Internet" in their titles or abstracts, research in this area must start from scratch. To the contrary, the literature on the uses and effects of hypermedia in an educational context can offer a useful starting point for those contemplating research on the World Wide Web. This monograph focuses on the theories and empirical studies that make up the cross-disciplinary hypermedia literature. We hope that this monograph will encourage the application of hypermedia theory and research to the study of formal and informal learning via the Web.

We are particularly hopeful that those interested in science education-both formally in the classroom context as well as those interested in informal science education-will make use of this review of the hypermedia literature. We began our journey into the hypermedia literature in order to better understand and evaluate the uses and effects of NISE's science Web site, "The Why Files" (http://whyfiles.news.wisc.edu). Thus it should be clear that we believe that science communicators of every sort can learn something from this literature and, we hope, our review of it.

Background

In 1945 Vannevar Bush, then director of the U.S. Office of Scientific Research and Development, predicted that the ways in which knowledge would be stored and accessed would be shaped by emerging technologies (Bush, 1945). In that article in *Atlantic Monthly* he proposed the creation of a device called a "memex," which would serve as "a sort of mechanized private file and library" (p. 106). Among the unique features of the memex was the manner in which users could access and annotate its contents. Bush (1945) claimed:

> It affords an immediate step...to associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the memex. The process of tying two items together is the important thing. (p. 107)

The key reason for the development of the memex, Bush claimed, was that the traditional mode of accessing and processing the information found in libraries did not mesh well with the workings of the human mind. He asserted that the human mind

> operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate web of trails carried by the cells of the brain. (p. 106)

He argued that traditional libraries, filled with discrete books using cumbersome cross-citation techniques, inhibited learning and integration of the immense quantity of scientific information that had been produced by researchers during World War II.

Thus, more than 50 years ago, Vannevar Bush had the foresight to propose the creation of a database that afforded instantaneous access to related information through associational links.

While Bush's description of the memex was based on the use of multiple microfilm viewers, the technology behind his idea would later be updated and the resulting product would be labeled "hypertext" by Ted Nelson in the late 1960s (Bevilacqua, 1989; Heller, 1990; Tsai, 19881989). The term hypertext is now being replaced by the term "hypermedia" because of the use of multimedia technology in many hypertext systems. Therefore, for simplicity's sake, we will use the term "hypermedia" as an inclusive label.

The defining feature of hypermedia is the use of nodes (packets of information, typically in the form of a "page") connected by links that may be easily traversed at the whim of the user (Horney, 1991; Shirk, 1992). As such, hypermedia is distinguished from traditional channels such as printed text and broadcast media by a high level of user control over the pace, order, and content, thus allowing use of information to be nonlinear or nonsequential (Duchastel, 1990; Horney, 1993; Shin, Schallert, & Savenye, 1994).

Nearly five decades after Bush's oft-cited article, the fundamental features of the memex-in the form of hypermedia-would take the United States by storm in the guise of the World Wide Web (The Internet, 1997). The World Wide Web is a graphics-based interface that is the most popular application available on the larger, more inclusive Internet (Rada, 1995). The Web was initially created in the early 1990s, but its entry into popular consciousness did not occur until almost mid-decade. The Web is, in effect, a massive hypermedia system (Astleitner & Leutner, 1995) that links together content as diverse as pornography and religion, science and myth, politics and pop culture.

Recent statistics on the popularity of the Internet and the World Wide Web reveal the massive growth in this medium over the past few years. A Harris Poll conducted in December 1997 and January 1998 (Taylor, 1998) revealed that over one-third of all U.S. adults use the Internet. This compared to only 7% using the Internet in a similar Harris Poll in September 1995 (Taylor, 1998). Mediamark (1998) places the proportion of U.S. adults using the Internet at a more conservative 23%, an increase of 260% since they began tracking Internet use. While some of the discrepancy in estimates is likely caused by a lack of clarity in questions about use of the Internet (does it mean use of the World Wide Web, use of electronic mail, or something else?), it is clear that a substantial proportion of the U.S. population is making use of this technology today, and that use has been increasing rapidly over the past several years.

Considering that the World Wide Web is in its infancy relative to other popular electronic media such as television and radio, use by between one-third and one quarter of the U.S. population is quite dramatic. However, like most innovations that enter a social system, adoption of the World Wide Web has not occurred equally across social strata. For example, Wirthlin Worldwide (1996) reports that the on-line audience is "well-educated, wealthy, and younger than the national average." Similarly, CommerceNet (1997) noted a bias toward males and people from higher social strata among Internet users, although these disparities were declining compared to only a year before. Hoffman and Novak (1998) have also found racial biases in Web use. All of these biases-and their gradual reduction over time-is what we would expect based on the study of the adoption of other then-new information technologies (Compaine, 1988).

Simply put, the World Wide Web is the world's largest hypermedia system. While it is not quite truly a "mass" medium, its level of use and substantial growth in recent years leads us to believe that it will soon follow the pattern of many other new communication technologies, such as radio and television, and become a mass medium with broad access and appeal. Recent "Web events" like the release of Kenneth Starr's report to Congress regarding President Clinton's affair with Monica Lewinsky will only speed the process.

The success of the Web compares favorably to early diffusion rates of AM radio, black-and-white television, color television, and the telephone, which took 10, 10, 17, and 70 years, respectively, to spread to half of the population (Rice, 1984). It is important to note, however, that only about 64% of American adults use .a computer at home, work, or school (Taylor, 1998). Since Web use is increasing much more quickly than computer use, ownership or access may—in time-limit the growth of Web use. However, the need for a large financial investment and high levels of technical know-how is now being reduced by the introduction of devices (e.g., Web TV©) that allow individuals to access the Web through a typical television set for an initial investment of only a few hundred dollars. This technological development may serve to reduce some of the social status and gender biases in Web use as well.

With the ever-increasing audience of the World Wide Web, the time has come for researchers to explore its uses and effects from a theoretical and empirical perspective. This effort would be hastened by the availability of a strong foundation in research and theory to which we could turn for insight. Unfortunately, the fact that the Web is a hypermedia system and that hypermedia systems have been studied for years now seems to have been lost on many of those with a research interest in the Web (Buckingham Shum & McKnight, 1997). Thus, this monograph focuses on the literature pertaining to the uses and effects of educational hypermedia as part of the basis for a research program on the use of the World Wide Web to convey scientific information.

Areas of Study Relevant to Research on the World Wide Web

The preceding section makes the argument that the World Wide Web is not something without precedent but instead merely an extension of hypermedia systems, which themselves have been available and studied closely by education researchers and others for more than a decade. It thus makes sense for any research attempting to examine the uses (and effects) of the World Wide Web to first consult the literature on the general uses and effects of hypermedia. While we make no claim that the uses and effects of the World Wide Web will be the same as those of hypermedia (indeed, later we will discuss some likely differences), we do believe that relevant theoretical and methodological insights may be gained from the hypermedia literature.

Any suggestion that researchers embark on a reading of "the hypermedia literature" begs the questions "What is the hypermedia literature?" and "Where do I find it?" The hypermedia literature is cross-disciplinary, scattered across at least four different but related fields: educational technology, cognitive psychology, computer/library and information science, and geography. In general, the focus of these four relatively distinct literatures can be described as follows: The research in educational technology is concerned with the design and application of

hypermedia systems for classroom or individual instruction. The primary focus tends to be on comparing the instructional effectiveness of entirely different media (e.g., hypermedia vs. print) or various hypermedia designs (e.g., hierarchically structured vs. unstructured). Educational researchers often focus on the role of individual differences, such as user age and expertise, as predictors of effectiveness of learning from hypermedia (e.g., Lanza & Roselli, 1991; Yang & Moore, 1995-1996). Consistent with Bush's (1945) vision, research in cognitive psychology—arguably the smallest component of hypermedia research-examines the structure of human memory and information processing and attempts to link it to the structure of computer information systems (e.g., Quillian, 1968; Wild, 1996). The computer and library information science literature looks at the usability and effectiveness of different human-computer interfaces-of which hypermedia is but one-for different information gathering tasks (e.g., Campagnoni & Ehrlich, 1989; Carmel, Crawford, & Chen, 1992; Thüring, Hannemann, & Haake, 1995). Finally, research originating in geography (and based on cognitive psychology) examines people's ability to represent physical and virtual spaces-including hypermedia-in memory and thus navigate effectively through these spaces (Crampton, 1992; Darken & Sibert, 1996; Kim & Hirtle, 1995; Kitchin, 1994; Shum, 1990). It also considers the potential influence of individual differences and external factors (such as characteristics of the space) on the effectiveness of navigation or "wayfinding expertise."

Theory Applicable to Educational Uses and Effects of the World Wide Web

Several domains of theory pertaining to hypermedia may help researchers theorize about the use of the World Wide Web for formal and informal education, including research on the structure of human memory and the link between that structure and the structure of hypermedia systems. Other theories focus on the impact of user control of instruction and motivation on the uses and effects of media. Early in the 1990s, hypermedia theorist David Jonassen argued that "hypertext design is theory-rich and research-poor" (Jonassen, 1992, p. 125). Seven years after this statement was made, we would still agree with its first component but less so with the second. Therefore, we will begin by briefly addressing the first part of the statement, grouping the theories into three general domains applicable to World Wide Web uses and effects.

Similarities Between Human Memory and Hypermedia

Psychologists studying the structure of human memory have proposed many theories about the way our minds work. A complete discussion of these models-and their similarities and differences-is well beyond the scope of this or any single paper. However, as the earlier quote by Bush (1945) revealed, many psychologists believe that bits of information in human memory are organized through their connections to each other on some (typically semantic) level. Theories taking this perspective on human memory exist in many fields and include research on schemas (e.g., Schallert, 1982; Wicks, 1992), levels of processing (e.g., Craik & Lockhart, 1972; Greenwald & Leavitt, 1984), domains of memory (e.g., Kintsch, 1972; Tulving, 1985), priming (e.g., Collins & Loftus, 1975; Iyengar & Kinder, 1986) and connectionism (e.g., McClelland, 1988; Smith, 1996). The act of learning from this perspective, therefore, is in large part the process of creating and maintaining meaningful links among concepts in memory (Jonassen, 1988; Nelson & Palumbo, 1992).

Theorists interested in the uses and effects of hypermedia frequently argue that the structure of hypermedia and the process of its use mimics this common conception of the structure of human memory and the function of information processing (e.g., Bieber, Vitali, Ashman, Balasubramanian, & Oinas-Kukkonen, 1997; Churcher, 1989; Jonassen & Wang, 1993; Kozma, 1987; Lucarella & Zanzi, 1993; Marchionini, 1988; Shin et al., 1994; Shirk, 1992). Jonassen (1988) notes that "because hypertext is a node-link system based upon semantic structures, it can map fairly directly the structure of knowledge it is representing." (p. 14) Claims such as these are used as theoretical rationales for the hypothesized superiority of hypermedia as a learning tool compared to other, more constrained and linear media that cannot represent the structure of a knowledge domain so precisely. Churcher (1989) argues that "where hypertext is highly structured and indeed is the structure of the domain of knowledge and that structure/system is to eventually become the users' conceptual model it strongly suggests hypertext as a more effective learning environment." (p. 245) Thus, the argument made by many hypermedia advocates is that, because hypermedia can be designed to emulate the appropriate links among concepts in a particular knowledge domain (as judged by experts), learners patterning their own mental models on the hypermedia system will develop expert-like schema in terms of both content and structure (e.g., Churcher, 1989; Jonassen, 1988; Jonassen &Wang, 1993).[1]

However, some theorists believe that there are important differences between the structure and use of hypermedia systems and those of human memory. For instance, Nelson and Palumbo (1992) argue that, in reality

> At present, most hypermedia systems support linkages indicating only that one unit of information is somehow related to another unit of information, without specifying the nature of this relationship and a rationale for its existence....In contrast, human memory supports a much stronger linking mechanism that both establishes a relationship and conveys information about the associational nature of the link. (p. 290)

Despite this and other criticisms of claims of similarities between human memory and hypermedia, most hypermedia researchers who have taken a stance on the issue seem to agree that the parallels between the two are many and theoretically important.

The argument for the superiority of hypermedia over other media for learning is linked closely with theories about the most appropriate designs for hypermedia, which are, again, based on theories of human memory and information processing. Suggested designs include those that are relatively unstructured (so that the user may be completely free to choose his or her own path), hierarchically structured, structured as a network, or structured based on the "true" form of the domain of knowledge (e.g., Churcher, 1989; Nelson & Palumbo, 1992; Shirk, 1992; Yang & Moore, 1995-1996). Evidence pertaining to these theories will be discussed in the section below on hypermedia research.

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[1] Other reasons for why hypermedia should be more effective for learning than paper text have been reviewed by Tergan (1997).

Learner control. One of the more prevalent notions in educational technology theory is the role of learner or user control of instruction. Theoretically, the argument is that, when students are given the opportunity to control the (1) pace, (2) order, and/or (3) content of instruction, not only will they be able to "design" a more meaningful and individualized (and thus effective) lesson than a teacher but they will also be able to maintain their interest and motivation to learn so that the likelihood of future exposure and learning is increased (Kinzie, 1990; Kinzie, Sullivan, & Berdel, 1988; Milheim & Martin, 1991; Steinberg, 1989). The use of computer-aided instruction, especially via hypermedia, has been proposed as one possible means of providing different levels of learner control to students. Shin and her colleagues argue that "in a hypertext environment, use of learner control is inevitable, because hypertext creates nonsequential, dynamic, and multiple structures of information that allow learners with different interests to navigate multiple pathways through the information" (Shin et al., 1994, p. 33). Thus, according to the theory, the positive effects of hypermedia on learning should be greater than those of other modes of instruction that do not afford'a similar level of control and interactivity.

The theory of learner control has implications for the design of hypermedia systems in much the same way as do theories of human memory and information processing. Specifically, learner control can be conceptualized as a continuum ranging from complete control for the learner ("learner control") to complete control for the system or teacher ("program control") (Milheim & Martin, 1991). The level of control afforded the learner is a direct function of the design of the system, with less structured systems providing more user control than systems with a clear structure, such as hierarchical or expert-based systems. In addition, some systems offer what has been termed "instructional advisement," which can be considered a limited type of program control in that the system makes suggestions about the most appropriate movements but the user can over-ride the suggestions at any time (Shin et al., 1994). A "guided tour" with no real alternatives except for the choice of when to move to the next page would represent the minimum level of learner control in a hypermedia system-only control over pace is provided. The appropriate level of learner control to be built into a hypermedia system has become an empirical question, however, and will be addressed in a later section of this paper.

Motivation. One of the important mediators of the hypothesized effects of learner control on learning is the motivation produced (or maintained) by being in control of one's own instruction (Kinzie, 1990; Steinberg, 1989). Independent of the effects of learner control on motivation, however, variations in motivation have been hypothesized as important factors in learning from hypermedia. The motivational impact of self-efficacy-the feeling that one is capable of performing at a certain level-is an oft-cited predictor of learning (e.g., Bandura, 1982; Schunk, 1991).

Using somewhat more complex models of learning, other researchers have theorized that many different motivational variables, such as perceptions of the medium, self-efficacy, or gratifications sought from media use (i.e., goals), influence the quantity and type of effort invested in learning from any medium, which in turn influences learning directly (Elliott & Dweck, 1988; Eveland, 1997a, 1997b, 1998; Kelleher, 1996; Multon, Brown, & Lent, 1991; Salomon, 1983, 1984). Similarly, it has been argued that beneficial cognitive effects of the use of hypermedia will occur only for those who are highly motivated to learn from the content

available via this technology (e.g., Kinzie & Berdel, 1990). Jonassen and Grabinger (1993) offer an eloquent theoretical statement about the impact of motivations on learning from hypermedia:

> Learning depends on the purpose for using the hypertext, which in turn drives the level of processing....Learners can learn from hypertext, we argue, only if they actively construct knowledge, which they will do if they are accessing the information to fulfill a personally meaningful purpose and have a reasonable level of prior knowledge and interest in the topic. (p. 21)

Empirical Research on the Uses of Hypermedia

As noted earlier, it was once argued that the topic of hypermedia was "theory-rich and research-poor." (Jonassen, 1992, p. 125) While in some cases this is still true-for instance, little research has been conducted on the influence of hypermedia use on the structure of human memory-and in other cases the research evidence on a particular point is inconsistent, there has been a flowering of empirical research concerning hypermedia topics during the past decade. It is to this literature that we now turn.

Studies of the educational uses and effects of hypermedia vary greatly in terms of methodology and the quality of the application of those methods. Three research traditions dominate empirical research on hypermedia: traditional experimentation, qualitative interviews, and collection of computer logs of hypermedia use ("audit trail data"). In addition, many studies employ a mixed methods approach, using two or more of these methods in order to answer their research questions.

In this section, we will focus on research into how people use hypermedia. We will begin by addressing an important question about hypermedia usage: Do people take advantage of the opportunities afforded them to move nonlinearly through the information in the hypermedia system and, if so, how? We will then examine some of the important independent variables that influence the uses of hypermedia, such as system design, motivations, and individual differences. After our discussion of the uses of hypermedia, the next section of this paper will deal with research on the cognitive effects of hypermedia use.

Patterns of Movement Through Hypermedia

As previously noted, one of the defining attributes of hypermedia (and thus of the World Wide Web) is its associational organizational structure, which allows users to navigate in a nonlinear or nonsequential manner (Duchastel, 1990; Shin et al., 1994). However, because of the control users have over the content of hypermedia systems, nonlinear navigation is a possibility but not a requirement for those who choose to maintain a linear reading strategy. As Horney (1993) has noted, "Determined readers can...remain bound within a narrow pattern of behavior despite the presence of rich webs of opportunities" (p. 74). So, while a hypermedia system can be categorized as more or less nonlinear in its ***structure,*** so can the use of any hypermedia system be categorized as more or less nonlinear. These two measures are likely to be correlated, but rarely perfectly correlated. The question then becomes: How do people use hypermedia systems?

Few researchers have assessed the linearity of hypermedia usage directly, and the heterogeneity of terms and definitions in the few studies that have examined this issue make conclusions tenuous. In most cases, linearity of use is operationalized as observation of a direct path to goal-relevant information via a table of contents, index, or keyword search (e.g., linear use, hierarchical use, or "searching"). By contrast, the "Web surfing" equivalent in hypermedia research (e.g., nonlinear use, non-hierarchical use, or "browsing") refers to following associational links among concepts, often serendipitously or possibly with interest as the only motivation (Campagnoni & Ehrlich, 1989; Carmel et al., 1992; Leventhal et al., 1993; Marchionini & Shneiderman, 1988). Our own research (Eveland & Dunwoody, 1998) has defined linearity as following the default or encouraged path through a site, while nonlinearity is indicated when users make "side trips" off this default path to retrieve supplemental information or to change topics altogether.

The hypermedia literature indicates that movement through the content of a site is often governed by contingent conditions. Unfortunately, differences found within studies are difficult to compare because of the plethora of different operationalizations and terminology in the literature. The reader should take this into account when reading the remainder of this paper.

Influences on Hypermedia Use

At least two categories of variables seem to have some influence on the uses of hypermedia: motivations and individual differences. Motivations typically refer to the task assigned to the user (external), although motivations may come from within the person (internal) as well. The individual difference variable of primary concern to researchers is expertise (either "domain" or "system"), but differences in cognitive ability/style, age, and gender have also been addressed. It is important to note that most studies examine only one or a few variables and thus do not typically control for confounding factors statistically. However, the homogeneous subjects used in many studies may provide some means of control via design by holding some of these potential confounding factors relatively constant.

Motivations. Marchionini and Shneiderman (1988) have argued that patterns of hypermedia use vary depending on the task to which users are assigned, with browsing a function of less well-defined problems compared to searching, which takes place when problems are more precisely defined. Similarly, Gray and Shasha (1989) claim that links are most useful when searches are undirected and much less useful when one needs to answer a direct question. Strong empirical evidence was brought to bear on this issue by Qiu (1993). He demonstrated significant differences in the Markov models of system use based on whether the users were completing general or specific tasks. The general task produced more wandering (browsing) whereas the specific task produced a more directed search.

Barab, Fajen, Kulikowich, and Young (1996) found significantly different navigation patterns for a group given a specific problem to solve with a hypermedia system versus a group simply told to use the system in preparation for a test. Specifically, the group given the specific problem to

solve tended to more closely follow the "ideal path" (identified a priori by the researchers) through the content than did the test group.

Most recently, Calvi (1997) examined the use of navigation tools by users engaged in free versus task-oriented navigation of a hypermedia system. He found that while 85% of participants used the content list (similar to a hierarchical index) for the free navigation task, 85% of the participants used the map (and only 10% used the content list) for the task-oriented navigation. However, the qualitative nature of this study means that no significance tests were conducted.

Individual differences. Many hypermedia researchers have called for the examination of individual differences in the study of the uses and effects of the medium (e.g., Jonassen, 1988; Marchionini, 1989; Nielsen, 1995). While many types of individual differences may be important, the literature has tended to focus on ***system expertise*** (experience with and skill using the hypermedia system) and ***domain expertise*** (experience with and knowledge of the content area under study) as key factors, with much less effort devoted to a few other individual differences, such as cognitive ability/style, age, and gender.

Scholars have argued that "expert users who are specialists in the task domain will welcome the great power and control [of hypermedia], but novices to the system and task domain will likely benefit from limited menus and less [user] control" (Marchionini & Shneiderman, 1988, p. 78). A similar argument has been made by Leventhal and her associates (1993), who claim (and provide some evidence) that novices tend to make use of a hierarchical structure when provided rather than use the nonlinear options available in hypermedia. As they gain experience, they begin to move away from the structure, much like a child will remove the training wheels from a first bicycle after gaining some experience (for additional evidence, see Leventhal, Teasley, Instone, & Fat-hat, 1994). This might have important imphcations for using the Web to educate the general public because the level of expertise or background information for any given topic could vary tremendously.

Qiu (1993) found significant differences in the Markov models of hypermedia use of system experts and novices. His interpretation of the data was that experienced users of a hypermedia system tended to exploit the nonlinear options provided while inexperienced users tended to engage in more "linear browsing." Carmel et al. (1992) found that domain experts tended to browse fewer topics in more depth while novices tended to browse more topics in less depth. The overall differences in hypermedia use were moderate, however, because despite different methods of browsing, both novices and experts tended to browse as opposed to using a search strategy. System expertise aside, however, Beasley and Vila (1992) found that ***general*** intellectual ability, as measured by ACT scores, was unrelated to either linear or nonlinear (measured separately) patterns of hypermedia use.

At least three other factors have also been linked to patterns of hypermedia use: cognitive ability/style, gender, and age. As would be expected because of the relatively unstructured nature of hypermedia, people with greater visualization ability-the ability to perceive patterns of objects in space-are more capable of nonlinear browsing, while those with lesser abilities tend to make more frequent use of a hierarchical structure (Campagnoni & Ehrlich, 1989). In a study

of the influence of cognitive style on hypermedia uses and effects, Leader and Klein (1996) found significant differences between field-independent (i.e., analytical style) and field-dependent (i.e., global or holistic style) learners. Specifically, field-independent learners needed to access fewer than half of the number of screens to find information in a hypermedia database than did field-dependent learners.

Gender differences have proven significant in several studies. Based on a test of differences between Markov models, Qiu (1993) found that males are significantly different from females in terms of their hypermedia usage patterns. He interpreted his data to indicate that males are significantly more likely to use search-type strategies, while females tend to browse linearly through the content. However, the meaning of this interpretation is clouded somewhat by a lack of definition of these terms. Beasley and Vila (1992) found that females used a more linear strategy (defined as the frequency of using a "Next" button) compared to males, although this relationship only bordered on statistical significance. Because of different operationalizations, it is unclear whether this result is consistent or inconsistent with that of Qiu (1993).
Finally, Leventhal et al. (1994) compared the patterns of hypermedia use of adults (college students) and children (fourth graders) and concluded that the younger users tended to employ more exploratory strategies while the older users tended to be more structured in their searches of the system.

While these limited and sometimes conflicting findings do not do much to illuminate the reasons behind individual differences in hypermedia use, they do point to the necessity of considering them for future research. What is most important for future research is to begin to develop consistent conceptualizations and operationalizations of concepts such as search strategies or linearity of use so that studies are directly comparable.

In addition, there should be a greater effort to include controls for demographic variables such as age and gender when examining the effects of independent variables such as expertise, because these independent variables may be highly correlated with both demographics and hypermedia use and thus may represent spurious effects. Social scientists have long known that understanding reality typically requires a multivariate, not bivariate, approach, and this knowledge should be applied to the study of educational uses of hypermedia and the Web.

Empirical Research on the Cognitive Effects of Hypermedia

By comparison to the research on the uses of hypermedia, the available evidence on the effects of hypermedia is much more developed from both a theoretical and empirical perspective. A number of studies have examined the influence of hypermedia use on criterion variables such as interest/motivation and learning. Researchers have compared the relative effectiveness and efficiency of using hypermedia versus traditional paper text for learning, and they have examined how hypermedia structure, motivations and individual differences can moderate the influence of hypermedia use. We will examine each of these topics in turn, beginning with a discussion of the criterion variables that have traditionally concerned hypermedia researchers.

Criterion variables. Theories of the uses and effects of hypermedia discussed previously suggest that many possible variables may be influenced by the use of hypermedia. Theories of learner control predict that hypermedia use will increase or maintain the ***motivation of users*** because of its greater user control and ability to permit individualized content in comparison to other media. This argument is interesting because it implies that ***perceptions*** of control can motivate users, in addition to any effects on motivation due to the decisions made by users or the actual control that is relinquished to them. Thus, in this case direct measures of user control—both perceived control as well as the actual control exercised-would be important mediator variables in the effect of hypermedia on motivation.

Similarly, many different theories suggest that the ***characteristics of hypermedia*** can lead to increased knowledge of relevant content domains. Theories of learner control would suggest that these effects are at least in part mediated through increased motivation, but other explanations do not require the intermediate step of increased motivation.

Less common but still present in the literature are claims that hypermedia use can influence the ***structure of knowledge*** through the format of the hypermedia system itself.

Research has at least begun to examine all of these effects, with a primary focus on the acquisition of content knowledge, often measured as the effectiveness of finding (but not necessarily being able to recall or recognize at a later time) relevant information. Future research should make greater attempts to measure learning in more complex ways. In the study of communicating via the Web and other hypermedia systems, researchers should measure learning by factual recall and recognition, comprehension and understanding of difficult concepts, synthesis of information from multiple sources or perspectives, and application of information to relevant personal contexts. Because of the ability of hypermedia systems to demonstrate the connections between new information and one's stored knowledge, it is the more complex and useful forms of learning like integration and elaboration (rather than rote memorization) that the structure of hypermedia systems is more likely to encourage than traditional print or broadcast media.

Paper Text vs. Hypermedia

Research comparing the effectiveness of different media (e.g., print vs. television vs. radio) for learning has a long tradition in educational technology, communication, and psychology that continues today (e.g., Furnham, Gunter, & Green, 1990; Gunter, Furnham, & Gietson, 1984; Neuman, Just & Crigler, 1992). This research tradition has continued in the realm of computer versus paper text comparisons (e.g., DeFleur, Davenport, Cronin, & DeFleur, 1992; Obourne & Holton, 1988; Reinking, 1988; Rice, 1994) and has recently spawned research on the relative effectiveness of hypermedia versus paper text (Gray, Barber, & Shasha, 1991; Psotka, Kerst, & Westerman, 1993; Sundar, Narayan, Obregon, & Uppal, 1997). However, during the past decade or so, this research has become a rather controversial matter in some circles.

The criticisms of general media comparison research, of which the hypermedia versus paper comparisons are a component, center on the confound between medium and content. The critics

of these research efforts claim that any observed "effects" of one medium over another may be spurious because of differences in content or instructional strategy used in different media (e.g., Clark, 1983, 1985; Hagler & Knowlton, 1987). Others counter that when studies are properly conducted and interpreted, comparisons can produce useful and theoretically meaningful results (e.g., Kozma, 1994; Morrison, 1994; Shrock, 1994). We believe that the argument for continuing this line of research is most effectively justified by the fact that, in the real world, content and instructional strategy *do* vary across media because of the ease of their application in one medium compared to another; thus, to control all differences would produce studies with limited ecological validity (Ross & Morrison, 1993).

If the above argument is accepted, the question becomes: From which medium-hypermedia or traditional print-do people learn more effectively? While some of the results have been qualified by interactions with other variables, the general conclusion in the literature, based on a meta-analysis conducted by Chen and Rada (1996), is that hypermedia is more effective (though not necessarily more efficient) at producing information gain than paper text (see also Gray et al., 1991; Psotka et al., 1993). Of specific interest to researchers concerned with learning from the World Wide Web is that some authors claim (e.g., Heller, 1990) and limited evidence suggests (Leventhal et al., 1993) that hypermedia may be particularly effective for incidental learning. Some have found, however, that the superiority of hypermedia for learning generally may be moderated by the task at hand (e.g., Leventhal et al., 1993; Rada & Murphy, 1992). This point offers a fortuitous segue into research on the variables that have been found to influence the effectiveness of hypermedia for learning.

Moderators of Hypermedia Effects

Researchers studying the influence of hypermedia use have identified several variables that may increase or decrease the effectiveness of this medium for learning. Hill and Hannafin (1997) have argued that at least five factors influence learning from hypermedia: (1) metacognitive knowledge; (2) orientation to the hypermedia structure; (3) perceived self-efficacy; (4) system expertise; and (5) domain expertise. While we generally agree with this assessment, our review indicates the most evidence for three general factors as moderators of hypermedia effects: (1) hypermedia structure (which can influence orientation); (2) motivations such as, but not limited to, self-efficacy; and (3) individual differences such as learning strategies or system/domain expertise. We will examine the research evidence concerning each of these three variables in turn.

Hypermedia structure. The structure and amount of control afforded users in hypermedia have exercised a significant impact on the cognitive effects of the system in many studies, though results are conflicting. Early research conducted by Gray (1987) found that, when given greater control of the sequence of instruction, users comprehended more of the content immediately after exposure, although a retention test a week later indicated no differences between groups given greater or lesser control. Lee and Lehman (1993) found that providing high levels of control of the content to users, but combining that flexibility with instructional advisement, increased learning for those groups who had difficulty dealing with the greater levels of control. However,

the user control/instructional advisement combination did not influence-either positively or negatively-those who could learn well without the advisement.

In the context of learning from media, cognitive overhead may be defined as the amount of mental effort required to locate specific information and to understand how this information is oriented within a larger information source (i.e., a chapter in a book or a page in a Web site). Generally speaking, hypermedia use demands more cognitive overhead than the use of printed text because hypermedia use requires "a certain overhead of metalevel decision making, an overhead that is absent when the author has already made many of these choices for you" (Conklin, 1987, p. 40). One impact of different hypermedia structures could be to exacerbate the cognitive overhead hypermedia place on users (Oliver, 1996). Much of the research on hypermedia systems has described user feelings of being "lost" in hyperspace (Conklin, 1987) or, more generally, "disorientation" (e.g., Calvi, 1997). These feelings may be caused by both inexperience with the medium as well as poor site design. In any case, disorientation will increase the cognitive overhead required to make use of the site.

It is assumed by most psychologists that the capacity to process information is finite and is often exceeded by the information available in the environment. In order to deal with this limitation in cognitive capacity, users may not always devote an optimum amount of cognitive effort to all tasks. Therefore, if a Web site's design requires substantial cognitive effort simply to navigate through it (cognitive overhead), less effort will be available to invest in actual learning processes such as integration and elaboration (Eveland & Dunwoody, 1999). Since the amount of mental effort ***devoted to learning processes*** is a very important correlate of actual learning, site designs that are overly complex or not intuitive can cause disorientation, leading to increased effort devoted to cognitive overhead and thus a reduction in learning. Thus, it is not total effort expended, but specific types of effort, that encourage learning. But even setting immediate learning aside, if the site is too complex it might discourage individuals from ever returning or from seeking information elsewhere in the future, which may be an even more dangerous effect of poor site design and high cognitive load.

Some hypermedia system designs attempt to provide features to reduce the cognitive load imposed by the technology. A meta-analysis by Chen and Rada (1996) demonstrated that, consistent with the claims of some designers (e.g., Bieber et al., 1997), providing a graphical overview of the structure of the hypermedia system can increase the effectiveness as well as the efficiency of hypermedia use. While there is no direct evidence, it is likely that features such as maps reduce the cognitive load of using hypermedia systems and thus allow users to devote more effort to the processes of elaboration, synthesis, and integration which promote learning. A useful next step in this area of research would be to directly measure the cognitive load imposed by the site design, potentially making use of work in engineering that has attempted to address similar constructs (e.g., Wickens, 1992). This would allow researchers to determine empirically if the impact of site design on learning is truly mediated by the effect of site design on cognitive overhead. Similarly, researchers should make an effort to directly measure the amount of cognitive effort devoted to mental processes beneficial to learning, such as elaboration (Eveland, 1997b, 1998; Eveland & Dunwoody, 1999).

Examining just a few types of hypermedia structure variations, then, the evidence indicates that the structure of a hypermedia system can have a significant impact on learning from the system. However, the direction of the effects are not always in favor of greater freedom of navigational control. While greater control may provide opportunities for individualized learning and continuing motivation, some designs may turn over too much control to the user, thereby increasing cognitive load and decreasing learning.

Motivations. While scholars have argued that any sort of motivation may conceivably influence the effectiveness of hypermedia use (e.g., Jonassen & Grabinger, 1993; Kinzie & Berdel, 1990), the focus of research has been on external motivations as moderators of learning. Internal motivations would include the interest and desire to learn, self-efficacy, or goals determined by the individual, such as to be entertained or to pass the time. The study of self-imposed goals for the use of communication media is studied in the context of what are called media "uses and gratifications" (McLeod & Becker, 198 1). External motivations, on the other hand, are typically operationalized as tasks assigned to users by a teacher or experimenter and are typically categorized as either "closed" tasks or "open" ones (or sometimes "search" and "browse" goals, respectively). Closed tasks commonly entail finding a specific unit of information in a single location, whereas open tasks typically require the integration of small bits of information from several locations. Thus, open tasks are more complex but also more closely mimic meaningful learning.

A meta-analysis of the literature on the influence of external motivations on the effectiveness of learning from hypermedia (Chen & Rada, 1996) indicates strong support for the assertion that hypermedia is much more effective for learning on open tasks (those having general goals) than closed tasks (those having specific goals). According to the authors, each of seven studies identified as testing this hypothesis found supportive evidence, with a large average effect size (r = .63). Using more complex distinctions by asking several different types of questions that varied in their level of openness, Leventhal et al. (1993) found differences in the relative effectiveness of hypermedia versus print based on question type. A close reading of their tables reveals that the variability in effectiveness across all question types was much higher for the control group using a paper version of the content (means scores ranging from 0.29 to 1.76 for the paper group, compared to 1.16 to 1.51 for the hypermedia group). This greater variance in effectiveness caused by question type for the paper version indicates that the moderating effects of task (i.e., question type) are in fact *greater* for paper than hypermedia. Clearly, however, the external task assigned to hypermedia users has some influence on the effectiveness of the medium, which is better suited to synthesis and integration tasks than isolated fact-finding.

Individual differences. As with any medium, many individual-level variables may influence the amount of learning from hypermedia. Most research on individual differences in hypermedia effects has focused on two key variables: expertise and cognitive/learning styles.

Earlier, we noted that theories of learner control predict that greater levels of control for the user should produce higher levels of learning (Kinzie et al., 1988), but the notion of cognitive load suggests that too much control may potentially hinder learning by funneling mental effort from learning to orientation and navigation. Reviews of the literature have not found strong support for

the learner control hypothesis; instead, it appears that learner control is effective only for those subjects who are highly motivated or have greater expertise in the content domain and, thus, are better prepared to structure their own learning processes (e.g., Gay, 1986; Milheim & Martin, 199 1; Park, 199 1; Steinberg, 1989). Indeed, in their discussion of learning from hypermedia, Jonassen and Grabinger (1993, p. 20-21) argued that "browsing in a domain for which no properly developed schema have yet been constructed, or no obvious need has been identified, is not likely to lead to satisfactory knowledge acquisition." The implication of this is that the Web might be more effective for educating those with prior background or very high levels of interest in the topic at hand. Individuals who merely happen upon scientific information on the Web by chance may not benefit much from the experience even if they do take the time to explore the information.

Consistent evidence for the importance of domain expertise is available from the hypermedia literature. For example, Shin et al. (1994) found no difference between free-access (high levels of user control available) and limited-access (low levels of user control available) hypermedia conditions. for a group with substantial prior knowledge. However, a low-prior-knowledge group of users scored significantly ***lower*** on an achievement test in the free-access system than in the limited-access system. Of course, this effect of domain expertise on learning should also apply to media other than hypermedia, but it is valid to hypothesize that the effect of domain expertise and interest on learning is ***greater*** for hypermedia than other traditional media, suggesting an interaction between medium of communication and background factors. While this point is not directly addressed in the hypermedia literature, it is a fertile area for future research.

It should be noted that in addition to expertise in the content domain, hypermedia system expertise-characterized more generally as wayfinding expertise (e.g., Crampton, 1992; Kerr, 1990)—should also promote learning from hypermedia. Rada and Murphy (1992), for instance, found that hypermedia was a more effective search tool than printed text for a sample of system (hypertext) experts but that print was clearly more effective for hypermedia novices. Given the widespread experience with the paper media by literate Americans, this influence of system expertise on learning from hypermedia is unlikely to occur with a medium like books. Again, this suggests that there is an interaction between medium of communication and background experience when predicting learning, such that background experience with hypermedia has an effect on learning from hypermedia but background experience with books-being universally high in this culture - h a s no effect on learning from books.

Several recent studies have examined how cognitive strategies and learning strategies may moderate the cognitive effects of hypermedia use and have concluded that more active, conceptually based, and analytical learning styles are more conducive to learning from this medium. Lee and Lehman (1993) found that those with passive learning styles (operationalized as those scoring more than ½ standard deviation below their sample mean on an index called the "Passive Active Learning Scale") achieved lower learning scores than active and neutral learners when using a hypermedia system without instructional cues. Another study (Esichaikul, Smith & Madey, 1994) demonstrated that, when using hypermedia, those with learning styles favoring abstract conceptualization produced higher quality solutions to problems than those with learning styles favoring more concrete experience. Similarly, a study by Leader & Klein (1996) discussed

earlier indicated that field-dependent learners (those who have a global or holistic cognitive style) produced significantly fewer correct answers in their search of a hypermedia system than field-independent learners (those who have a more analytic cognitive style). However, significant interactions with type of search tool available indicated that this pattern only held in two of the four experimental conditions.

These effects, like those of interest or expertise, are likely to be found for other media as well. The question of whether these effects are stronger for hypermedia than for paper media remains unanswered by the literature. However, in some cases there is considerable theoretical reason to suspect that the effects are greater for hypermedia than other media, particularly when the individual difference is something like visualization ability or the ability to think abstractly. The argument is that a virtual environment, in which content disappears and reappears constantly, requires a greater ability to think abstractly and visualize the larger structure of information that would be explicit and concrete-literally in the hands of the user-for paper media.

Discussion and Conclusions

Conclusions from the Hypermedia Literature

The study of the uses and effects of hypermedia is a classic example of cross-disciplinary research. Unfortunately, seldom-if ever-do researchers in one domain cite the research in other domains. Some existing literature reviews completely ignore theory and research conducted outside of their home discipline. This review has tried to integrate the findings of research on hypermedia uses and effects regardless of the field in which it was originally conducted. Nonetheless, given the scattered nature of the research, we have no doubt inadvertently overlooked published hypermedia-related studies ourselves.

As a cross-disciplinary area of theory and research, the hypermedia literature tends to be fragmented and to suffer from broad and inconsistent use of conceptual terminology and operationalizations. Thus, despite the existence of a substantial literature, few studies on any single topic are truly comparable, either conceptually or operationally. This has forced the few laudable attempts at meta-analysis to rely on an extremely small number of studies composed largely of unpublished dissertations and conference papers that are not easily available to most researchers (see Chen & Rada, 1996).

Further, even in published studies, statistical analyses are often not correctly applied or, even worse, the appropriate designs for accurate tests of hypotheses (e.g., use of control groups or comparisons of effects between hypermedia and other media) are not implemented. Astleitner and Leutner (1995, p. 395) have noted, "A lot of the research in the field of learning with hypermedia still comes from computer scientists who, in general, do not dispose of that high-quality methodological repertoire concerning empirical investigation which is usually common to social scientists." For instance, one glaring omission in this research is the design of studies to test for interactions between medium and background characteristics like expertise in order to determine whether the effects of expertise on learning from hypermedia are particularly acute for hypermedia or simply another manifestation of effects that occur with any medium.

Aside from flaws in research design (i.e., lack of random assignment) or analytical errors, two other consistent drawbacks in the empirical research on the uses and effects of hypermedia are (1) the failure to control for extraneous variables in observational research and the use of extremely homogeneous samples-typically either elementary students or graduate students-in experimental studies; and (2) the failure to measure and analyze theoretically meaningful mediator variables such as perceived user control, motivation, and cognitive load.

All these factors make it difficult to derive any solid generalizations from the existing hypermedia literature. Instead, at this stage the literature on hypermedia uses and effects more realistically can provide researchers with a template for choosing potentially important independent and moderator variables for further study in the context of the World Wide Web, and to learn from the early attempts of others.

To facilitate future multivariate research, we have arranged those variables that have been commonly studied in the hypermedia literature into a preliminary causal model based on an information processing perspective (Figure 1). This model represents our view of how these variables should be arranged; although many of the links have been consistently supported by research, in general this is a hypothesized model. In particular, this model includes many of the important (and often missing) mediating variables in a more complex model of the effects of hypermedia on learning.

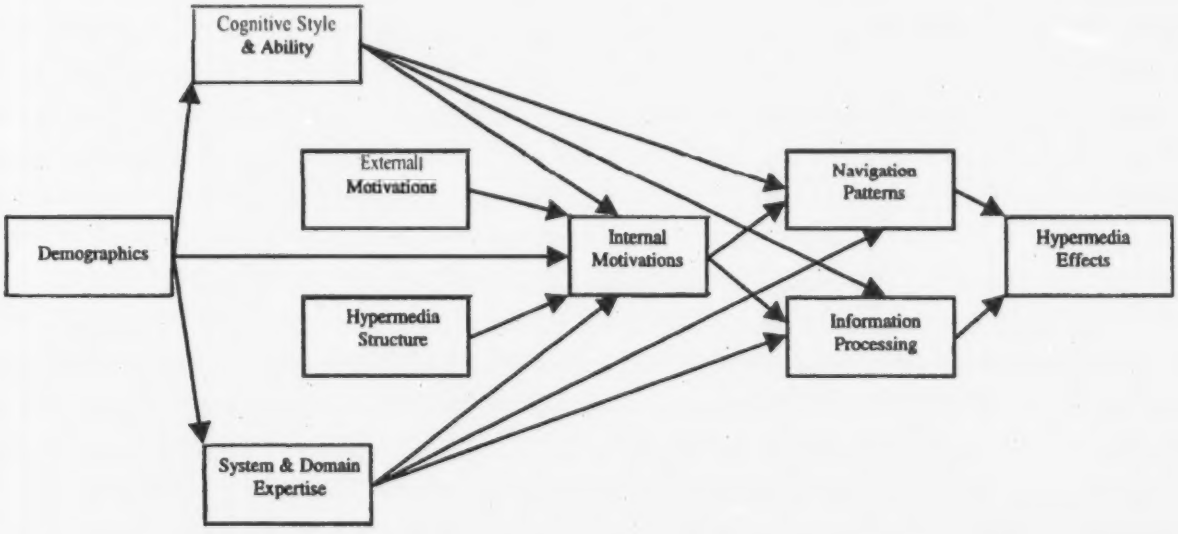

Figure 1.

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In this model, demographic variables are considered exogenous. Demographic variables are presumed to directly influence levels of expertise (both system expertise and domain expertise), cognitive style and ability variables, and internal motivations (e.g., gratifications sought from the use of the Web, self-efficacy). External motivations (i.e., tasks), hypermedia structure, cognitive style/ability, and domain and system expertise are also believed to have an impact on internal motivations. Internal motivations, cognitive style/ability, and domain and system expertise are expected to directly influence navigation patterns through hypermedia and information processing in the form of elaborative processing. These navigation patterns and information processing activities, in turn, serve as the key mediating variables for hypermedia effects. It should be noted that this model is a slightly modified version of the "cognitive mediation model" advocated by the first author (Eveland, 1997a, 1997b, 1998).

A concrete example combining experimental manipulations, self-report measurement of exogenous and mediating variables, and electronic observation of navigation patterns will help to illustrate this model. Learning about science from The Why Files Web site could be examined by altering the ***hypermedia structure*** to produce a simple, relatively "linear" and a sophisticated, relatively "nonlinear" version of the site. Participants would be randomly assigned to one or the other of these versions, using instructions to provide ***external motivations*** for (randomly) either learning or entertainment. Both the site structure and the assigned motivation would contribute to perceptions of self-efficacy-which is one form of ***internal motivation-for*** completing the assigned task. Self-efficacy would also likely be influenced by pre-existing levels of cognitive ability and expertise with both the system (in this case, the Web) and the content of the story (e.g., wildfires, genetic cloning), as well as by demographic variables such as socio-economic status or gender.

Self efficacy, cognitive ability and both forms of expertise would likely have substantial impact on the qualitative type and quantity of ***information processing*** (e.g., more effort spent elaborating, integrating and synthesizing vs. simple repetition or selective scanning) and the electronically observed ***patterns of navigation*** (e.g., seeking additional information available about certain subtopics such as the use of controlled burns in the case of wildfires and ethical considerations in the case of cloning) through the site. Finally, these navigation patterns (which determine the content, order, and length of exposure to specific information in the site) and information processing activities are the direct determinants of learning.

Why Might Web Uses and Effects Differ from Those of Hypermedia?

Despite our focus on the hypermedia literature, we do not take the position that the uses and effects of the World Wide Web itself will perfectly mirror those of other hypermedia systems. Indeed, the Web is unlike any other hypermedia system in existence because of its massive size, broad access, and multiple, independent authors. Thus, the direct and automatic application of all hypermedia research to the Web context without consideration of these differences is probably inappropriate (Smith, Newman, & Parks, 1997).

Two of the most important variables identified in hypermedia research are expertise (system and domain) and motivation. In most of the studies described above, the variance in each of these

variables was rather limited. A lack of variation in expertise or motivation can mask the potential moderating effects of these variables on the relationship between hypermedia use and information processing and learning. Thus, the results of research might change when the context produces greater variation in levels of expertise and motivation.

For instance, motivation has typically been based on directions from teachers or experimenters to conduct a focused search versus a less focused browse of a small hypermedia system. On the Web, the variety of motivations (e.g., learning, entertainment) is likely to be much greater and more likely to be internally generated, as would be expected considering the differences in context between classroom learning from a typical hypermedia system and "surfing the Web." How will this increased variance in motivation influence findings about the uses and effects of the Web that were not apparent in past research?

Similarly, the level of expertise of users of the Web varies widely-from first-time users to computer programmers (system expertise) and from elementary school children to Ph.D.'s in a content area (domain expertise). However, most past research has focused on very homogeneous subject populations such as schoolchildren of the same age. How will this wide variety in expertise on the Web influence findings about the uses and effects of the Web compared to the existing research?

The World Wide Web is also infinitely larger and more complexly organized than the largest hypermedia system examined in the studies above. This can only exacerbate the problems of disorientation or being lost in hyperspace (Calvi, 1997; Dias & Sousa, 1997; Kahn & Landow, 1993; McKnight, Dillon, & Richardson, 1989; Psotka et al., 1993; Roselli, 1991; Stanton & Barber, 1994) that users have felt in the smaller systems. In addition, the much wider variety of content on the Web means that someone who is a domain expert at one moment may become a complete domain novice with the click of a mouse button. How will this great variety of content and massive size influence World Wide Web uses and effects? This is an important question for those who plan to conduct research on the effectiveness of communicating via the Web.

Another variable on the Web that is not studied in the hypermedia literature is the perceived credibility of the source. Whereas a hypermedia system used in a classroom or experimental setting is likely to come from a single source and be given high ratings for credibility, information on the World Wide Web varies tremendously in origin and (we would argue) credibility. How will user credibility judgments influence the uses and effects of the Web? What role will skepticism, cynicism, trust, and quality assessment skills play in learning from the Web? These are important questions for future research to address.

Conclusion

A substantial literature dispersed across several fields addresses the educational uses and effects of hypermedia systems, of which the World Wide Web is by far the largest and most complex. To make this literature more readily available to researchers engaged in the nascent study of communication and education via the World Wide Web, this paper has reviewed this cross-disciplinary literature and suggested some avenues for further study.

Due to its cross-disciplinary nature, the hypermedia literature uses a variety of conflicting conceptualizations and operationalizations that make generalizable patterns of findings difficult to identify. However, researchers can learn from and build upon this literature by understanding the important issues that have been raised and clarifying ambiguities due to poor definitions of concepts and inconsistent operationalizations. It is only by addressing these problems that the study of the role of hypermedia and the World Wide Web in learning can move forward.

It is our hope that this review will encourage Web researchers to delve into the hypermedia literature and make use of it in developingtheir own theories and research projects. While the hypermedia literature does not provide any definitive or generalizable answers for us as far as learning via the World Wide Web, it does have a decade head start on Web research in asking important and relevant questions, and thus we still have much to learn from it.

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